

explosion; but, on the other hand, cordite, although it contains as much as 58 per cent. nitro-glycerine, owing to the fact that it contains also vaseline, gives a temperature lower than that of ballistite containing only 30 per cent. nitro-glycerine and no vaseline. Of course, the minimum deflection is the one due to gun-cotton, which contains no nitro-glycerine.

Similar experiments have also been repeated with other explosives and with different charges, and, in every case, the same comparative results have been obtained.

The above refers only to a part of the experiments which have been carried out so far. Another series is now in progress for determining the other necessary elements which will be required before we can accurately express the value of these deflections of the galvanometer in degrees of temperature. One important element which comes into play is the inertia of the galvanometer itself in connection with the shortness of the time during which the maximum temperature exists, and there are also other points which are being investigated, and these will form the subject of a further communication.

We have, however, thought it advisable not to delay communicating the above results, as already the described method shows the possibility first of all of obtaining approximately an idea of the temperature during explosion, and, secondly, it shows a clear way by which the comparative temperatures for various explosives can be determined. These, taken in connection with the results shown in our former communication, will serve, we hope, to give a better knowledge of the different modern explosives which are now commonly used.

“The Spectrum of α Aquilæ.” By SIR NORMAN LOCKYER, K.C.B., F.R.S., and A. FOWLER. Received January 18,—Read February 8, 1900.

[PLATE 1.]

The study of enhanced lines throws considerable light on the spectrum of α Aquilæ, the peculiarities of which were first described by Professor Pickering* and Dr. Scheiner† in 1889. In this spectrum the lines of hydrogen are strong and broad, but the additional lines, instead of being faint and sharp as in most other stars of this class, are faint and diffuse. Dr. Scheiner stated that these apparent bands were identical with the most conspicuous groups of lines in the solar spectrum, and further that this appearance of the spectrum can be

* Third Annual Rep. Henry Draper Memorial, p. 5.

† ‘Ast. Nach.’ 2924.

imitated by holding a rather faint drawing of the solar spectrum at such a distance that the individual lines are no longer visible.

From a consideration of the photographs taken at Harvard College Observatory, Professor Pickering suggested in 1891 that the diffuseness of the lines in the spectrum of α Aquilæ and certain other stars was perhaps due to a rapid rotation of the star.* That rotation might be capable of producing such effects had already been suggested by Abney in 1877.†

Photographs taken at Kensington with large dispersion, during 1892, led to the adoption of Professor Pickering's view, and the spectrum of α Aquilæ was classed with that of β Arietis, in which we apparently got the same lines quite sharp.‡

In 1895 Dr. Scheiner again referred to this spectrum,§ and suggested that it represents a transition stage from the first to the second type; as an alternative explanation, he mentions the view that the spectrum may be a composite one, in which a spectrum of the first type is superposed upon one of the second.

In a recent paper|| Dr. Vogel has discussed the spectrum of α Aquilæ chiefly with reference to its motion in the line of sight, but he also considers the question of the haziness of the lines. He refers to some experimental photographs which depict the solar spectrum with its lines broadened by a cylindrical lens, or by a photograph taken out of focus, and states that spectra of this kind have been obtained in which the close lines run together so as to produce a spectrum resembling that of α Aquilæ. He adds that the exact comparison of the two spectra shows that the agreement is not perfect, in particular that the G group is hardly indicated in the spectrum of α Aquilæ, while it comes out strongly in the solar spectrum when thrown out of focus. He accordingly places the spectrum of α Aquilæ in his Class Ia 3., of which α Cygni, β Cassiopeiæ, and Procyon are members,¶ and further concludes that the lines are broadened in consequence of rapid rotation, without, however, referring to previous suggestions to the same effect.

The general result is that while Vogel classes α Aquilæ with α Cygni, which, on the meteoritic hypothesis, is a star of increasing temperature, the work at Kensington indicates that it should be classed with stars like β Arietis, which there is every reason to believe to be cooling. This difference as to facts is so important that the whole question has been re-investigated.

* 'Annals Harv. Coll. Obs.,' vol. 26 (1891), Pt. I, p. 21.

† 'Monthly Notices R.A.S.,' vol. 37, p. 278.

‡ 'Phil. Trans.,' A, vol. 184 (1893), p. 697.

§ 'Pub. Ast. Obs. zu Potsdam,' vol. 7, Part II, p. 232.

|| 'Sitzber. Akad. Berlin,' Nov. 1898; translated in 'Astrophys. Journ.,' Jan. 1899.

¶ 'Astrophys. Journ.,' vol. 2 (1895), p. 346.

The Kensington Photographs.

An investigation of the spectrum of α Aquilæ was commenced at Kensington in 1890, and, with the various instruments employed up to 1892, fifteen negatives were obtained.* In all these the lines were ill defined, and it was decided to take a special series of photographs "in order to determine whether the haziness of its spectrum lines is invariable."† Since then a considerable number of photographs has been obtained, but although variations have been suspected it is found difficult to establish their reality. One thing seems quite certain, namely, that the lines are always ill defined.

At the Royal Society Conversazione in 1894, enlarged copies of photographs of the spectra of α Aquilæ and β Arietis were exhibited which indicated that Pickering's view that the haziness of the lines is due to rotation is probably correct.

Dr. Scheiner's experiment of photographing the solar spectrum out of focus has since been repeated; but while it was found possible to produce bands in this way, only a few of them agree with those in α Aquilæ. Among these coincident bands are 4031—4036 (Mn), 4046 (Fe), 4064 (Fe), 4132—4135 (chiefly Fe), 4143·6—4144 (Fe), 4226·9 (Ca), 4250·3—4251 (Fe), 4260·2—4260·6 (Fe), 4271·3—4271·9 (Fe).

On the other hand, by taking an out-of-focus enlargement of a negative of the spectrum of β Arietis, the violet being put more out of focus than the blue, the spectrum of α Aquilæ is almost perfectly reproduced (see Plate). The difference in width of the bands appears to be sufficiently explained by the gradually increasing dispersion in prismatic spectra as the violet end is approached. With the instrument employed at Kensington a tenth-metre near λ 4046 is represented by a distance on the photographs about 1·4 times as great as that corresponding to the same difference of wave-length near λ 4384; and since the velocity which would produce a displacement of one-tenth metre at λ 4384 would produce a displacement of 0·92 tenth-metre at λ 4046, the displacements on the photographs for the same velocity, with the particular instrument employed, will be in the proportion of 1 to 1·29 at λ 4384 and λ 4046 respectively.

Classification of the Star.

This experiment appears to be a sufficient demonstration of the essential similarity of the spectra of α Aquilæ and β Arietis, so that the former conclusion that the two stars should be classed together is perfectly justified.

* 'Phil. Trans.,' A, vol. 184 (1893), pp. 685—688.

† *Ibid.*, p. 696.

According to the earlier work at Kensington, stars like β Arietis were classed in Group V α ,* that is, between stars like Sirius and those like Procyon. The work on enhanced lines which has been done since then enables us to carry on the work of classification with much greater precision, since we have now a means of estimating relative temperatures with considerable accuracy. In this way we learn that stars at each stage of temperature fall into two groups, one of which represents stars of increasing temperature, and the other including stars of decreasing temperature. α Aquilæ and β Arietis fall in the latter group, and are to be regarded therefore as stars in which photospheres have formed. The later work on the classification of spectra has shown that it is sufficient for all practical purposes to include both in the Sirian group of stars.

This question of classification is further elucidated by a more detailed examination of the spectrum of α Aquilæ in relation to α Cygni and the Sirian stars. The foregoing demonstration of the likeness between α Aquilæ and β Arietis leads us to expect that the origins of the lines in the spectrum of α Aquilæ will be the same in the main as those of β Arietis and Sirius. In these stars the temperature of the absorbing vapours is intermediate between that of the arc and that at which enhanced lines appear alone, so that the spectra show both arc and enhanced lines. The origins of the chief enhanced lines in the spectrum of Sirius have already been investigated,† and practically the same lines occur in β Arietis. Besides these enhanced lines there are several well-known arc lines, such as the iron triplets and the blue line of calcium, which can be readily identified. The origins of some of the lines of both classes are shown in the plate which accompanies this paper, enhanced lines being shown at the bottom and arc lines at the top.

It will be seen that enhanced lines of iron appear in α Aquilæ, but have not the same relative intensity as in α Cygni; the most enhanced line of iron (λ 4233·3), for example, which in α Cygni is represented by a very strong and well-defined line, is in α Aquilæ very weak and hazy. On the other hand, some of the enhanced lines of iron less refrangible than H γ are fairly prominent. The principal enhanced lines of magnesium, strontium, and titanium are also certainly present, as shown in the plate. The enhanced double line of silicium at $\lambda\lambda$ 4128·1, 4131·1, if present, is very weak, a moderately strong hazy line, rather less refrangible than the silicium double, making it rather difficult to determine whether the latter is certainly present.

Among the arc lines present are those of the iron triplet in the violet ($\lambda\lambda$ 4045·90, 4063·76, 4071·79), which are clearly seen, but the iron triplet in the blue ($\lambda\lambda$ 4383·70—4415·27) cannot be identified

* 'Phil. Trans.,' A, vol. 184 (1893), p. 726.

† 'Roy. Soc. Proc.,' vol. 65 (1899). Plate 7.

with certainty. The place occupied by the manganese quartet ($\lambda\lambda$ 4030·88—4035·88) is covered in the spectrum of the star by what appears to be a broad hazy line, which is probably composed of the individual components of the quartet merged together. The arc line of calcium at λ 4226·90 is one of the most prominent lines in the spectrum.

The classification of the spectrum of α Aquilæ may therefore be considered as settled; it does not sufficiently resemble α Cygni to justify Vogel's view that it should be classed with that type of star, while, on the other hand, apart from the haziness of the lines, it does bear a very strong resemblance to β Arietis and other Sirian stars, and should therefore be classed with them.

[*Note, February 8.*—In a later publication* Vogel places α Cygni in his Class Ia 2, with Sirius, β Arietis, &c., but this does not materially modify the conclusions arrived at.]

There are other points on which this demonstration of the similarity of α Aquilæ and β Arietis may be brought to bear, among them being the determination of the lines most suitable for the measurement of the velocity of the star in the line of sight, and the approximate determination of the velocity of rotation necessary to produce the observed haziness of the lines.

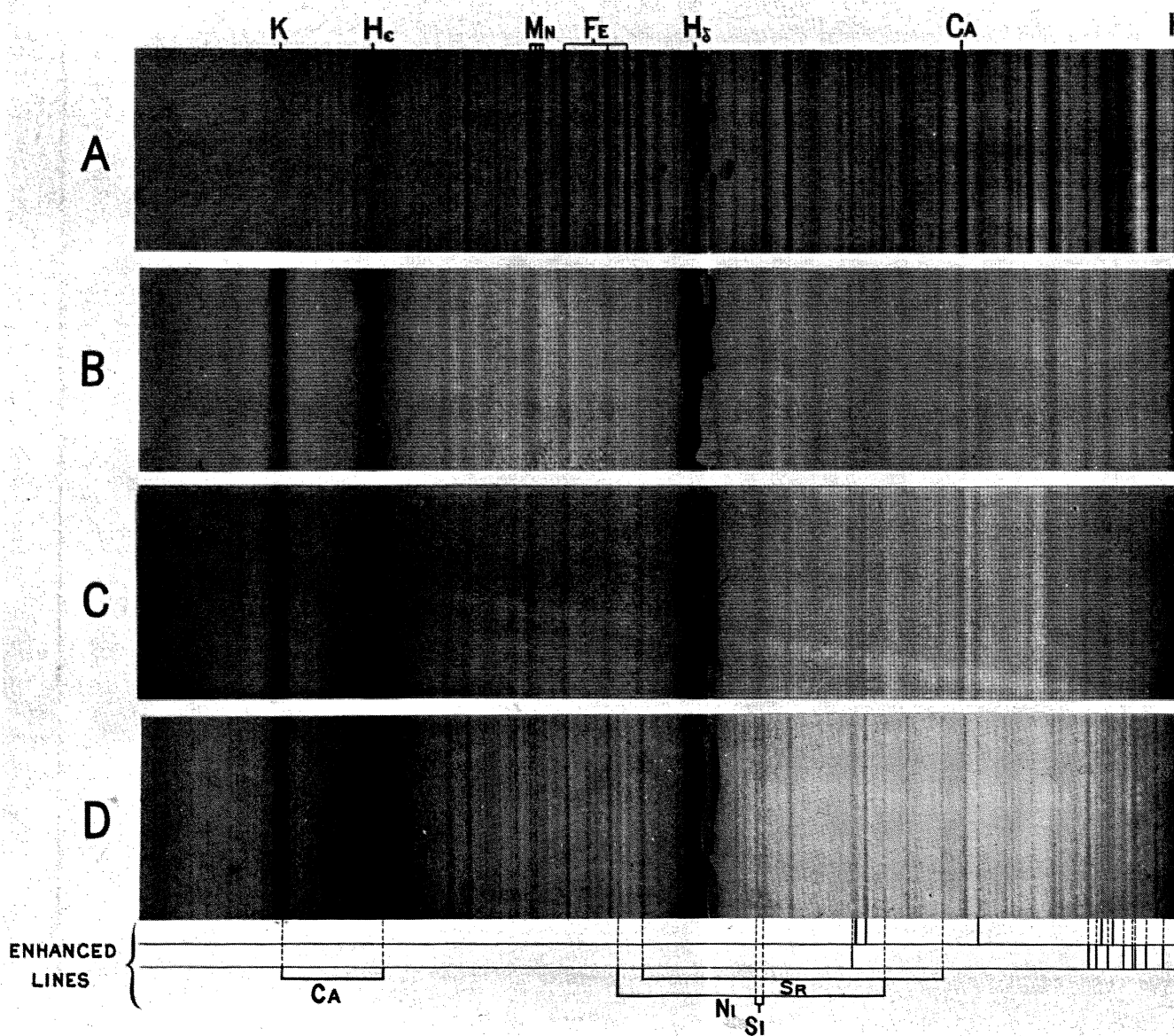
Lines suitable for the Determination of the Velocity of the Star in the Line of Sight.

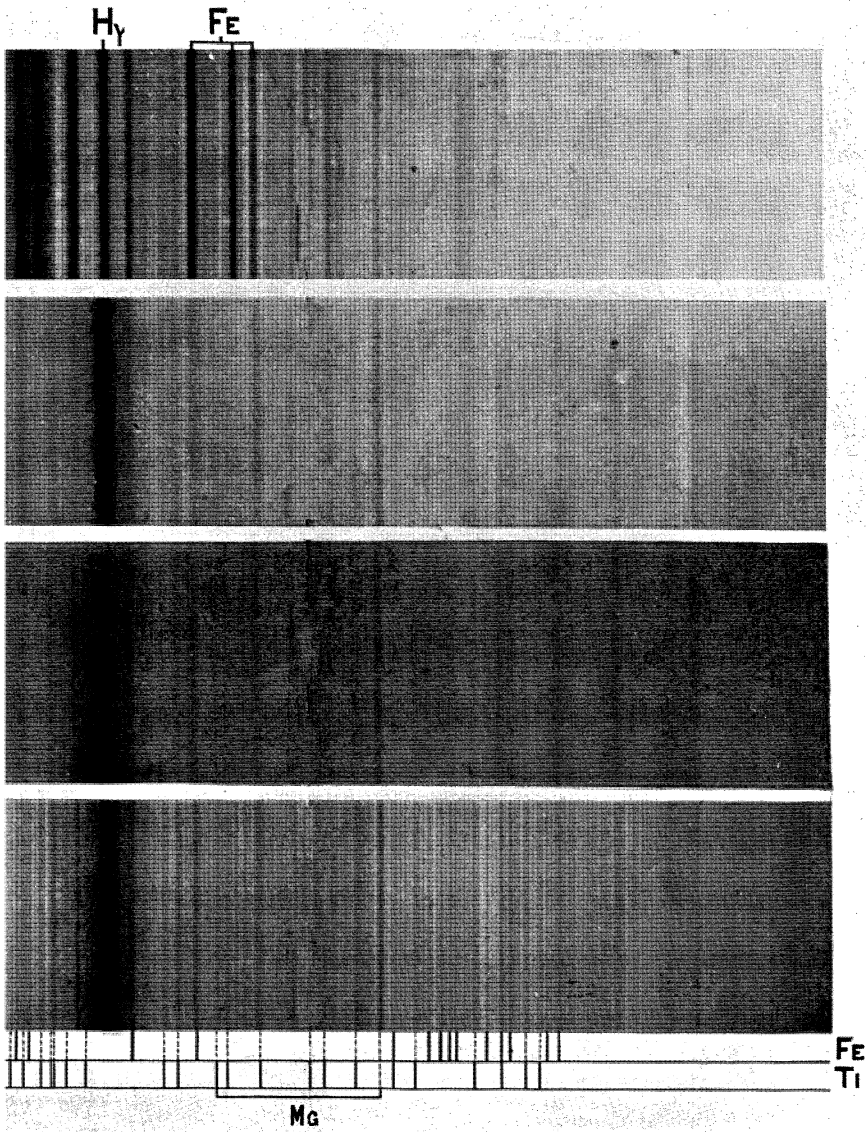
For the measurement of the velocity of α Aquilæ, Deslandres has employed comparison spectra of hydrogen, iron, and calcium.† Vogel, however, questions the advantage of using the spectra of iron and calcium as comparisons for this purpose, on the ground that “the lines in the spectrum of α Aquilæ are so diffuse . . . that between H_β and H_δ no lines except those of hydrogen and the magnesium line at λ 4481 can be identified with known lines.” He himself has used the H_γ line alone as a term of comparison, and concludes that there are no indications of a periodic change in the velocity of the star in the line of sight, such as was supposed by Deslandres.

We now know with certainty the origins of a considerable number of the lines in α Aquilæ, so that measurements of the velocity of the star are placed on a surer basis. Since the spectrum of α Aquilæ is simpler than that of the sun, some of the broad lines do not represent confused groups of lines, but are broadened individual lines. The latter class of lines, when of known origin, seems to be well adapted for the

* ‘Pub. Ast. Obs. Potsdam,’ 1899, vol. 12, Part I, p. 49.

† ‘Comptes Rendus,’ vol. 121 (1895), p. 629.





measurement of the velocity of the star, for though they may be still somewhat wide, they are much less so than the lines of hydrogen. Among these broadened individual lines are :—

Iron (enhanced lines).—4178·95, 4233·25, 4385·55, 4549·64.

„ (arc lines).—4045·90.

Titanium (enhanced lines).—4417·98, 4443·98.

Strontium.—4215·66.

The enhanced line of magnesium at 4481·3 is usually sharply defined in stellar spectra, but the fact that it is generally fluffy in the comparison spark disqualifies it for accurate measurements.

The Velocity of Rotation.

Assuming that β Arietis represents the spectrum of α Aquilæ as it would appear if the axis were directed towards the earth, we can get a general idea of the velocity of rotation necessary to produce the observed broadening of the lines. For this purpose lines which occur in groups are obviously unsuitable, but we can utilise the lines to which attention has just been drawn. Taking the enhanced line of iron at λ 4178·95, we find that its thickness is increased from about two to four tenth-metres, and this corresponds to a surface velocity of the star at the equator of about 45 miles per second, supposing that the axis is perpendicular to the line of sight. Similar measurements of the broadening of the magnesium line 4481·3 yield a velocity of about 40 miles per second. Since only a small portion of the surface of the star could exhibit the effects of the maximum velocity, it is probable that these values are too low, really representing the equatorial velocity of rotation resolved along the line of sight with reference to a point somewhere between the limb and centre of the star.

Dr. Vogel gives reasons in his paper for supposing the velocity of rotation to be possibly 27 kilometres (16·8 miles) per second, but this determination does not depend upon measurements of individual lines.

General Conclusions.

The investigation of the Kensington photographs of the spectrum of α Aquilæ has thus led to the following conclusions :—

(1) Apart from the general haziness of the lines, the spectrum presents no unfamiliar features.

(2) The spectrum is of the Sirian type, showing enhanced lines of various metals, and a smaller number of arc lines.

(3) A rapid rotation of the star, as first suggested by Pickering, appears to be a simple and sufficient explanation of the peculiarities of the spectrum.

DESCRIPTION OF PLATE.

A. Solar spectrum, purposely out of focus.

B. α Aquilæ.C. β Arietis, purposely out of focus.D. β Arietis, in focus.

The photographs of the spectrum of α Aquilæ which have been obtained at Kensington since 1890 were nearly all taken by Messrs. Fowler, Baxandall, Shackleton, and North. Mr. Baxandall has assisted in the determination of origins.

The photographic plate has been prepared from the original negatives by Sapper Wilkie, R.E.

“The Velocity of the Ions produced in Gases by Röntgen Rays.”

By JOHN ZELENY, B.Sc., B.A., Assistant Professor of Physics, University of Minnesota. Communicated by Professor J. J. THOMSON, F.R.S. Received February 15,—Read March 1, 1900.

(Abstract.)

The sum of the velocities with which the positive and the negative ions that are produced in gases by the Röntgen rays move when in a unit electric field has already been determined by an indirect method by E. Rutherford.* In the experiments here described the velocity was determined in a number of gases for the positive and negative ions separately, by comparing the ionic velocity directly with that of a stream of gas. The stream of gas was made to flow between two concentric cylinders, which were maintained at different potentials. By passing a narrow beam of Röntgen rays through the cylinders at right angles to their length, a narrow layer of ionised gas was produced. Due to the electric field between the two cylinders, the ions of this layer tended to move radially towards, or away from, the axis of the cylinders, but at the same time they were carried along by the stream of gas. Of the ions of this layer which travelled inwards, those that started from the inner surface of the outer cylinder were carried a distance X by the gas stream before they reached the surface of the inner cylinder.

This distance is dependent directly upon the mean velocity of the gas stream, and inversely upon the difference of potential between the two cylinders. For obtaining the difference of potential which must be used to allow the ions to be carried a certain distance along the tubes by the gas stream the inner cylinder was divided at some distance from the beam of rays into two parts, insulated from each

* E. Rutherford, ‘Phil. Mag.’ November, 1897.

